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Terms	Documents
L3 and L16	0

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	DB=PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD; PLUR=YES; OP=OR		
L20	l3 and L16	0	L20
L19	l3 and l15	0	L19
L18	l15 and l16	0	L18
L17	l15 same L16	0	L17
L16	center adj reflection	539	L16
L15	center adj intensity	506	L15
L14	frame and l11	1	L14
L13	l5 and L11	4	L13
L12	l3 and L11	0	L12
L11	5386285.pn. or 5479173.pn. or 5617085.pn. 5805103.pn. or 6134497.pn. or 6191704.pn. 6292753.pn.	14	L11
L10	l8 and L9	2	L10
L9	image	2480066	L9

L8	l6 and L7	2	L8
L7	warn$3	217918	L7
L6	l4 and L5	2	L6
L5	collision	140985	L5
L4	l2 and L3	3	L4
L3	upramp and downramp	21	L3
L2	radar	78367	L2
L1	(upramp and downramp) near sweep	0	L1

END OF SEARCH HISTORY

Refine Search

Search Results -

Terms	Documents
frame and L11	1

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L12	l3 and L11	0	L12
L11	5386285.pn. or 5479173.pn. or 5617085.pn. 5805103.pn. or 6134497.pn. or 6191704.pn. 6292753.pn.	14	L11
L10	l8 and L9	2	L10
L9	image	2480066	L9
L8	l6 and L7	2	L8
L7	warn$3	217918	L7
L6	l4 and L5	2	L6
L5	collision	140985	L5
L4	l2 and L3	3	L4
L3	upramp and downramp	21	L3

L2	radar	78367	L2
L1	(upramp and downramp) near sweep	0	L1

END OF SEARCH HISTORY

Refine Search

Search Results -

Terms	Documents
L6 and L7	2

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Search: L8

Refine Search

Recall Text Clear Interrupt

Search History

DATE: Saturday, July 03, 2004 Printable Copy Create Case

Set Name side by side	**Query**	**Hit Count**	**Set Name** result set
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L7	warn$3	217918	L7
L6	l4 and L5	2	L6
L5	collision	140985	L5
L4	l2 and L3	3	L4
L3	upramp and downramp	21	L3
L2	radar	78367	L2
L1	(upramp and downramp) near sweep	0	L1

END OF SEARCH HISTORY

L10: Entry 2 of 2 File: USPT Dec 24, 1996

DOCUMENT-IDENTIFIER: US 5587929 A
TITLE: System and method for tracking objects using a detection system

Brief Summary Text (7):
Radar, lidar, sonar and other detection techniques are frequently used to detect objects without requiring visual contact. The application of such detection techniques has been expanded to include use in both passive and active collision avoidance systems. In such collision-avoidance applications, a detection system is used to detect objects in the path of a moving mobile machine (referred to as a host vehicle). When an object is detected, appropriate steps are taken to avoid collision with the host mobile machine. Such steps can include halting the host mobile machine, altering the host vehicle's path, or simply alerting an operator of the host mobile machine that there is a threat of collision.

Brief Summary Text (8):
One challenge for collision avoidance systems using conventional detection systems is that of minimizing false alarms. Depending on the system characteristics, threshold settings, and operating environment, conventional systems may be susceptible to false alarms. For example, in an environment having a high concentration of dust particles, such particles may appear as obstacles to a lidar (light detection and ranging) system.

Brief Summary Text (9):
A further challenge for collision avoidance systems is that of tracking an object while the host mobile machine is in motion. As the host mobile machine moves along its route, an object detected by a detection system mounted on the host mobile machine may appear to move relative to the host mobile machine. For detectors that sense an instantaneous image at each sample time, the object may appear to jump from one position to the next. Such jumps may give rise to questions such as whether an object is really present, whether the signal return is just noise, whether them is more than one object, and so on.

Detailed Description Text (3):
The present invention is a tracking technique for use with a detection system. The detection system, such as radar, lidar, sonar, or other detection system, can be mounted on a host mobile machine. The detection system is used to detect objects in the path of, or in the general vicinity of the host mobile machine. Such an application is useful in implementing collision avoidance techniques.

Detailed Description Text (5):
For ease of discussion, the invention is discussed in terms of an example application as illustrated in FIG. 1. In this example application, the host mobile machine 104 is a mining truck, and the detection system 108 is a forward-looking radar system mounted on host mobile machine 104 to detect objects 102, such as rocks, in the host mobile machine's path.

Detailed Description Text (6):
Although the invention is discussed in terms of this example application, after

reading the following description, it will become apparent to one skilled in the relevant art how the invention could be implemented in alternative environments with alternative detection and navigation systems. Other applications can include, but are not limited to, collision avoidance and/or navigation systems for aircraft, automobiles, locomotives, and other means of conveyance.

Detailed Description Text (7):
According to the example application, host mobile machine 104 is an autonomous mining truck that, during normal operations, is not driven by a human operator. Instead, host mobile machine 104 is operated by a computer system along a defined route. The radar detection system 108 is used to sense objects 102 in the host mobile machine's path.

Detailed Description Text (8):
The characteristics of the specific detection system chosen depend on the application. For collision avoidance and/or navigation systems for a relatively slow moving mobile machine (such as an automobile or a mining truck), the system is most concerned about objects that are near the mobile machine (e.g., within 300 meters). For high speed applications such as jet aircraft collision avoidance systems, early warning is required and therefore, the longer distances are important.

Detailed Description Text (10):
FIG. 2 is a block diagram illustrating the detection system 108 and a navigation system 212. Detection system 108 includes a sensor 204 and a detection processing system 208. In this example, sensor 204 is a radar sensor that senses the presence of objects 102 within its field of view. In one embodiment, sensor 204 can be a forward-looking sensor to detect objects only in front of host mobile machine 104. In an alternative embodiment, sensor 204 can be used to sense objects in any desired direction and can provide up to 360 degrees of coverage.

Detailed Description Text (14):
Because of these specific requirements of this example implementation, detection system 108 is implemented as a millimeter wave radar system. Such a system provides high resolution tracking with a very narrow beam-width. As a result, during a scan across the field of view, several adjacent returns may be received for each object 102 in host mobile machine's 104 path. Thus, each individual object may be represented by several datapoints each in its own bin.

Detailed Description Text (24):
In the example embodiment using a radar sensor 204, when an object 102 is detected by sensor 204, the returns are given in terms of time and amplitude. This data must be converted into range and power data at each horizontal scan angle. In the example embodiment this is done by performing a fast-fourier transform (FFT) on the data at each horizontal scan angle.

Detailed Description Text (32):
According to this example, sensor 204 is a frequency modulated continuous wave (FMCW) millimeter-wave radar unit operating at a frequency of 77 GHz. Sensor 204 scans a one degree beam (illustrated as theta in FIG. 3) across a sixty-four degree horizontal field of view 304 at one degree intervals. RF energy centered at approximately 77 GHz is transmitted in an upramp portion and a downramp portion. The received signal is mixed with this transmitted signal and an intermediate frequency (IF) signal results. When radar energy is reflected off objects in the radar's field of view, the range of these objects is directly proportional to frequencies in the IF signal.

Detailed Description Text (33):
An anti-aliasing filter is used to eliminate frequencies above 500 KHz in the IF signal. The cutoff frequency of the anti-aliasing filter is 390 KHz which

corresponds to a range of 100 meters. The IF signal is also run through a R 4 filter which eliminates the effect of the fallout of radar power as the radius from the source increases. This means that an object will have approximately the same power at 100 meters as it does at 5 meters.

Detailed Description Text (34):
The portion of the IF signal that corresponds to the upramp time and the downramp time are digitized and sent to detection processing system 208. Each upramp portion and downramp portion of the signal is digitized into 256 words or time increments. Frame 216 is created by detection processing system 208 by performing a fast fourier transform (FFT) on the downramp portion of the data at each one degree interval. The FFT transforms the 256 points of digital data into the power domain resulting in 128 values that correspond to reflected power values at 1 meter increments up to 128 meters from sensor 204. Since the cutoff frequency of the anti-aliasing filter is at 390 KHz, the values beyond 100 meters are ignored and frame 216 is created with 64 azimuth positions and power values out of 100 meters.

Detailed Description Text (35):
An additional step that could be performed at this stage is to perform an FFT on the upramp portion and use the information on the object shift in the upramp and downramp portion to calculate the relative speed of the objects in the field of view 304. In the present invention this step is not being done because of limited processing power available on the example hardware, but it is recognized that this step could add relative speed information. This step is also not being done because at this stage a single object 102 in frame 216 may be represented by several datapoints (power values in frame 216. Frame rates of 4 to 5 Hz on frame 216 enable the objects 102 to be viewed several times per second have reduced the need for relative speed information in the present application where the host mobile machine's top speed is 35 miles per hour. Viewing the objects 102 in multiple beams and at frame rates of 4-5 Hz is more advantageous for finding smaller power objects than taking the time to calculate the relative speed of the objects.

Detailed Description Text (42):
In some conventional tracking systems, objects 102 being tracked are at very long distances from the radar. An object's range can be anywhere from a few kilometers to several hundred kilometers. As a result, each object appears as a single datapoint in a single bin. Such objects 102 could be easily tracked by mapping the single datapoint associated with each object onto the next frame of data.

Detailed Description Text (44):
In practice, the accuracy of radar is constrained by environmental effects, target characteristics, and instrumentation error. Environmental effects can include multi-path signal propagation and refraction. Target characteristics can include target surface texture that results in individual scattering centers, and rounded edges which result in non-uniform returns around the edges of the target. Instrumentation error, which can be minimized with proper alignment and calibration techniques, constrains performance as well. Additionally, parallax error may result in this application where sensor 204 is mounted above the ground and used to track objects 102 on the ground.

Detailed Description Text (45):
Because these effects can result in object images that appear to wander and glimmer, it is difficult to map an object 102 from one frame to the next. The inventors have conceived of a solution to overcome this problem. According to the inventors' solution, objects 102 are not mapped per se as objects. Instead, the inventors' solution individually maps each datapoint to the subsequent frame. As a result, each datapoint of an object 102 in one frame is mapped into the subsequent frame.

Detailed Description Text (61):

In one embodiment, the threshold is determined using a constant false alarm rate (CFAR) algorithm. This algorithm provides a means for determining a threshold for each range bin 404 by comparing the value of a range bin 404 to the mean of its neighbors, or some grouping of its neighbors. See pages 392-395 in "Introduction to Radar Systems" by Merrill I. Skolnik, McGraw-Hill, Inc., copyright 1980, for a description of a CFAR radar receiver.

Detailed Description Text (62):
In a preferred embodiment, each datapoint is compared to the mean of the datapoints in the five range bins 404 in front of the datapoint and the five range bins behind the datapoint and to the same range bins 404 in the radar beams to the left and the right of the datapoint. In this way a window around the datapoint with the dimensions of three beams in azimuth by 11 in range increments is formed. The mean of the 32 datapoints around the datapoint is found and if the point is greater than 3 times this mean then the point is above the threshold and the point is considered valid otherwise the value of the range bin is reduced to zero. Various other criteria with regard to the neighbors around the datapoint could be used to determine the threshold.

Detailed Description Text (64):
As stated above the step 520 of blob coloring is performed to determine which datapoints can be combined to indicate the presence of an object. Blob coloring is a technique used in the computer vision field to label objects in a computer image. A blob coloring algorithm is given on page 151 of "Computer Vision," Ballard and Brown, Prentice-Hall, Inc., 1982. This step is now described in greater detail. FIG. 7 is a diagram illustrating a representative scenario for blob coloring. FIG. 8 is an operational flow diagram illustrating the process of blob coloring according to one embodiment.

Detailed Description Text (83):
FIG. 9 is a block diagram illustrating an example implementation of detection system 108 interfaced to navigation system 212. Detection system 108 in this example embodiment includes a main processor 904, a DSP (digital signal processor) 908, and interfaces 916 to the actual detection unit in this case radar 920.

Detailed Description Text (84):
Additional proximity radar units 922, 924, 926 can be provided to trigger proximity alarms. If proximity radar units 922, 924, 926 are provided, parallel I/O 912 may be required to interface the alarms to processor 904.

Detailed Description Text (86):
Main processor 904 provides threshold setting requirements and system resolution information to DSP 908 via signal path 968. Main processor 904 also generates and sends commands for frame rate, resolution, and start/stop scanning to radar 920 via signal path 970.

Other Reference Publication (2):
Lakshmanan et al., "A Deformable Template Approach to Detecting Straight Edges in Radar Images," IEEE Transactions-PAMI, date unknown, pp. 1-28.